Aerospace Manufacturing

(SIC 372, 376)

SIGNIFICANT POINTS

- Skilled production, professional specialty, and technician jobs comprise the bulk of employment.
- Increased employment opportunities will stem primarily from continued growth in the commercial aircraft sector.
- Earnings are substantially higher, on average, than in most other manufacturing industries.

Nature of the Industry

The aerospace industry is comprised of companies producing aircraft, guided missiles, space vehicles, aircraft engines, propulsion units, and related parts. Aircraft repair and modification, and aerospace research and development are also included. The combination of advanced production processes, a highly trained workforce, and significant research and development has allowed U.S. industry to remain dominant in the international market.

The aerospace industry can be divided into two large segments: firms producing aircraft, engines, and parts; and firms producing guided missiles and space vehicles, propulsion units, and parts. The larger employer of the two segments—firms producing aircraft, engines, and parts—can be further divided according to what they produce: civil aircraft or military aircraft.

Firms producing civil transport aircraft comprise the largest segment of civil aircraft. Civil transport aircraft are produced for air transit businesses such as airlines and cargo transportation companies. These craft range from small turboprops to jumbo jets and are used to move people and goods all over the world. Another segment of civil aircraft is general aviation aircraft. These aircraft are produced for private individuals and corporations. General aviation aircraft range from the small two-seaters designed for leisure use to corporate jets designed for business transport. The last segment of civil aircraft, civil helicopters, are commonly used by police departments, emergency medical services, and businesses such as oil and mining companies that need to transport people to remote work sites.

Military aircraft and helicopters are purchased by governments to meet national defense needs, such as delivering weapons to military targets and to transporting troops and equipment around the globe. Some of these aircraft are specifically designed to deliver a powerful array of weaponry to military targets with tremendous maneuverability and low detectability. Research into the materials, electronics, and manufacturing methods used to produce military aircraft has resulted in a vast number of commercial applications. Aircraft engines used in civil and military aircraft are not produced by the aircraft manufacturers but by aircraft engine manufacturers. These manufacturers design and build engines that match the thrust of the engine to the size and flight characteristics of the aircraft. Aircraft manufacturers may use engines produced by different companies on one model aircraft, depending on the initial design of the aircraft.

The smaller segment of the aerospace industry includes firms producing guided missiles and spacecraft. Firms producing guided missiles and missile propulsion units are supported primarily by military and government demands. Although missiles are predominantly viewed as offensive weapons, improved guidance systems have led to their increased use as defensive systems. Applications of missile propulsion units also include their use in launching satellites into orbit.

Space vehicles are predominantly satellites. Firms producing space vehicles also produce craft for space flight and interplanetary scientific exploration. Consumers of spacecraft include the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), telecommunications companies, television networks, and news organizations. Satellites, in addition to military uses, observe weather and the Earth in general, monitor and explore the cosmos, aid in search and navigation, and enable many communications services. The businesses that build satellites are usually separate from the businesses that operate them once they are in orbit.

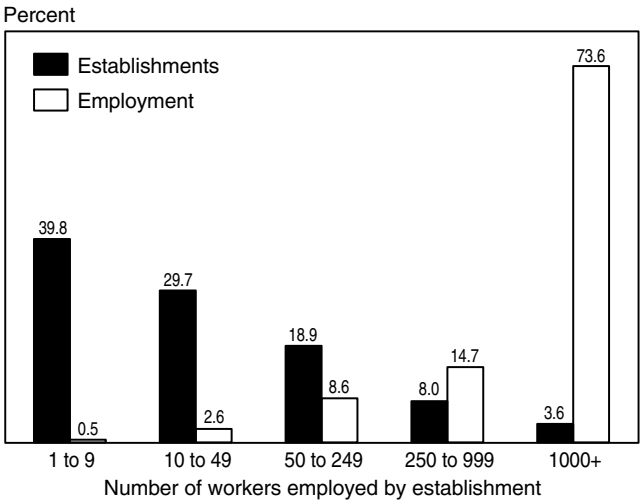
About 1,828 establishments make up the aerospace industry. Most are concentrated in the aircraft and parts sector, which has about 1,726 establishments, compared to 102 in the guided missiles and space vehicles sector. In the aircraft and parts industry, most establishments are subcontractors that manufacture parts and employ fewer than 50 workers (table 1). In contrast, almost 16 percent of the guided missile and spacecraft establishments employ over 1,000 workers each, compared to less than 3 percent of the aircraft and parts firms. Nevertheless, over 70 percent of the jobs in both aircraft and parts and guided missiles and spacecraft are in large establishments that employ 1,000 or more workers (chart).

Table 1. Percent distribution of establishments in aerospace manufacturing by establishment size, 1997

Establishment size (number of workers)	Aerospace manufacturing	Aircraft and parts	Guided missles and space vehicles
Total	100.0	100.0	1 00.0
1-9	39.8	41.0	19.6
10-49	29.7	29.8	28.4
50-249	18.9	18.7	21.6
250-999	8.0	7.6	14.7
1,000 or more	3.6	2.9	15.7

SOURCE: U.S. Department of Commerce, *County Business Patterns,* 1997

Although the majority of establishments in aerospace manufacturing employ fewer than 50 workers, most jobs are in large establishments



Source: U.S. Department of Commerce, *County Business Patterns*, 1997

The Federal Government traditionally has been the biggest customer of the aerospace industry, accounting for more than half of industry sales for many years. As defense purchases have declined substantially in recent years, the value of sales to the Government now accounts for about two-fifths of total industry sales. The vast majority of Government contracts to purchase aerospace equipment are awarded by DOD. NASA also is a major purchaser of the industry's products and services, mainly for space vehicles and satellites. The decline in defense purchases has increased the importance of civil aviation customers, who now are the dominant customer segment.

The aerospace industry is dominated by a few large firms that contract to produce aircraft with Government and private businesses, usually airline and cargo transportation companies. These large firms, in turn, subcontract with smaller firms to produce specific systems and parts for their vehicles. Government purchases are largely related to defense. Typically, DOD announces its need for military aircraft, satellites, or missile systems, specifying a multitude of requirements. Large firms specializing in defense products subsequently submit bids, detailing proposed technical solutions and designs, along with cost estimates, hoping to contract this new business. Firms may also research and develop materials, electronics, and components relating to their bid, often at their own expense, in order to enhance their chance of winning the contract. Following a negotiation phase, a manufacturer is selected and a prototype vehicle is developed and built, and then tested and evaluated. If approved by DOD, the aircraft is put into production.

Commercial airlines and private businesses typically identify their needs for a particular model of new aircraft based on a number of factors, including the routes they fly. After specifying requirements such as range, size, cargo capacity, and seating arrangements, the airlines invite manufacturers of civil aircraft to submit bids. Selection is ultimately based on a manufacturer's ability to deliver reliable aircraft that best fit the purchaser's stated market needs at the lowest cost and at favorable financing terms.

The way in which commercial and military aircraft are designed, developed, and produced is undergoing significant change in response to the need to cut costs, product development time, and manufacturing time. Firms producing commercial aircraft have reduced development time drastically through computer-aided design (CAD), which allows firms to design an entire aircraft, including the individual parts. The electronic drawings of these parts are sent to subcontractors, who use them to program their machinery. Recently, product development teams are increasingly being used through every phase of development, teaming customers, engineers, and production workers together to make decisions concerning the aircraft. Additionally, the military has changed its design philosophy, using available commercial off-the-shelf technology when appropriate, rather than developing new customized components.

Working Conditions

The average aerospace production employee worked about 44 hours a week in 1998, compared to less than 42 hours a week throughout manufacturing and less than 35 hours a week across all industries.

Working conditions in aerospace manufacturing facilities vary. Many new factories are spacious, well lit, and modern, in contrast to older facilities. Work environments usually depend on the occupation. Engineers, scientists, and technicians frequently work in office settings or laboratories, although production engineers may spend much of their time with production workers on the factory floor. Production workers, such as welders and other assemblers, may have to cope with high noise levels. Oil, grease, and grime are often present, and some workers may face exposure to volatile organic compounds found in solvents, paints, and coatings. Heavy lifting is required for many production jobs.

Cases of work-related injury and illness in the aircraft and parts sector were approximately 8.7 per 100 full-time workers in 1998, higher than 3.2 per 100 workers in the guided missiles sector. In comparison, cases of work-related injury and illness throughout the private sector averaged 7.1 per 100 workers.

Employment

Aerospace manufacturing provided over 615,000 wage and salary jobs in 1998—nearly 524,000 of them in the aircraft and parts sector and nearly 92,000 in the guided missiles, space vehicles, and parts sector. According to the most recent data available from the Aerospace Industries Association, more than 4 out of 10 industry employees worked on civil aircraft, nearly 3 out of 10 worked on military aircraft, and another 3 out of 10 worked on guided missiles and space vehicles.

The largest numbers of aerospace jobs are in California, although many are also located in Washington, Texas, Connecticut, Kansas, Florida, and Arizona.

Occupations in the Industry

The design and manufacture of the technologically sophisticated products of the aerospace industry require the input and skills of various workers. Skilled production, professional specialty, and technician jobs comprise the bulk of employment. A significant number of employees are employed in managerial and administrative support occupations, stemming from the need to manage the design process and

factory operations, coordinate the hundreds of thousands of parts that are assembled into an aircraft, and ensure compliance with Federal recordkeeping regulations. A larger proportion of workers in the aerospace industry has education beyond high school than the average for all industries.

The aerospace industry is on the leading edge of technology and is constantly striving to create new products and improve existing ones. The industry invests a great amount of time and money on research and development, and much of the work is performed by professionals and technicians—who make up 29 percent of the aerospace workforce (table 2). A bachelor's degree in a specialized field, such as engineering, is required for many of these jobs; and a master's or doctoral degree is preferred for a few. Two years of technical training after high school is favored for many technician occupations.

Professionals and technicians develop new designs and advances to existing designs. Some also do basic aeronautical research. *Aerospace engineers* are integral members of the teams that research, design, test, and produce aerospace vehicles. Some specialize in areas such as structural design, guidance, navigation and control, and instrumentation and communication. Electrical and electronics, industrial, and mechanical engineers also contribute to the research, development, and production of aerospace products. For example, *mechanical engineers* help design mechanical components and develop the specific tools and machines needed to produce aircraft, missile, and space vehicle parts, or they may design jet and rocket engines. *Electrical* and *electronics engineers* specialize in electronic equipment used in aerospace products, such as radar and other transmission and communication equipment. *Engineering technicians* assist engineers, both in the research and development laboratory, and on the manufacturing floor. They may help build prototype versions of newly designed products, run tests and experiments, and perform a variety of other technical tasks. One of the earliest users of computer-aided design software, the aerospace industry continues to use the latest computer technology. *Computer scientists, computer engineers, computer programmers,* and *systems analysts* are responsible for the design, testing, evaluation, and set-up of computer systems that are used throughout the industry for design and manufacturing purposes. A multitude of computer and electronic systems are central to the function of aerospace products, and computer professionals work to integrate the vast array of data these systems provide into a cohesive set of information useful to pilots.

Managers and administrators accounted for nearly 18 percent of industry employment. Most persons advance to these jobs from professional occupations. Many managers in the aerospace industry have a technical or engineering background and supervise teams of engineers in activities such as testing and research and development. *Industrial production managers* oversee all workers and lower-level managers in a factory. They also coordinate all activities that relate to production. In addition to technical and production managers, *financial managers*, *purchasing agents*, *cost estimators*, and *accountants* are needed to negotiate with customers and subcontractors and track costs.

Of all aerospace workers, 42 percent are employed in production-related jobs in precision production, craft, and repair occupations, and operator, fabricator, and laborer occupations. Many of these jobs are not specific to aerospace and can be found in other manufacturing industries. Many production jobs are open to persons with only a high school education; however, special vocational training after high school is preferred for some of the more highly skilled jobs.

Precision production occupations make up a large part of production jobs. *Precision assemblers* usually specialize in one assembly task; hundreds of different assemblers may work at various times on producing a single aircraft. Assemblers may put together parts of airplanes, such as wings or landing gear, or install parts and equipment into the airplane itself. Those involved in assembling aircraft or systems must be skilled in reading and interpreting engineering specifications and instructions.

Table 2. Employment of wage and salary workers in aerospace manufacturing by occupation, 1998 and projected change, 1998-2008

(Employment in thousands)

Occupation	1998 Employment Number	1998 Employment Percent	1998-2008 Percent change
All occupations	615	100.0	21.9
Precision production, craft and repair	174	28.2	19.4
Machinists	29	4.7	32.0
Inspectors, testers, and graders, precision	25	4.0	8.0
Blue-collar worker supervisors	22	3.6	26.3
Aircraft mechanics and service technicians	19	3.1	11.2
Aircraft assemblers, precision	16	2.7	19.5
Electrical and electronic equipment assemblers	11	1.8	23.8
Professional specialty	137	22.3	26.7
Aerospace engineers	25	4.1	11.8
Mechanical engineers	15	2.5	27.4
Industrial engineers	14	2.4	31.2
Computer engineers and scientists	15	2.4	28.9
Electrical and electronics engineers	10	1.7	41.7
Systems analysts	7	1.2	85.9
Executive, administrative, and managerial	112	18.1	25.1
Engineering, mathematical, and natural science managers	10	1.6	43.0
Purchasing agents	8	1.3	25.0
General managers and top executives	7	1.1	19.8
Operators, fabricators, and laborers	87	14.2	23.6
Machine setters, setup operators, and tenders	41	6.7	24.2
Hand workers, including assemblers and fabricators	33	5.4	23.6
Helpers, laborers, and material movers, hand	10	1.6	20.6
Administrative support, including clerical	54	8.9	11.9
Production planning and expediting clerks	11	1.8	11.9
General office clerks	8	1.3	26.1
Secretaries	7	1.2	-3.1
Technicians and related	40	6.4	18.2
Engineering technicians	29	4.7	23.4
Service	8	1.3	15.3
All other occupations	4	0.6	26.0

Machinists make parts when there are too few needed to be mass-produced. They follow blueprints and specifications and are highly skilled with machine tools and metalworking. *Sheet metal workers* study blueprints to determine specifications for the pieces they are shaping. They cut or punch out pieces they need and finish by fastening the seams with bolts, rivets, or other devices. *Tool* and *die makers* possess highly developed skills. They are responsible for constructing precision tools and metal forms, called dies, which are used to shape metal. Increasingly, as individual components are designed electronically, these skilled craft workers must be able to read electronic blueprints and set up and operate computer-controlled machines.

Inspectors, testers, and *graders* are responsible for performing numerous quality and control and safety checks on aerospace parts, from the beginning stages through the final production. Their work is vital to ensure the safety of the aircraft.

The remaining jobs in the industry were in administrative support, clerical, and service occupations. Most of these jobs can be entered without education beyond high school. Workers in administrative support and clerical jobs help coordinate the flow of materials to the worksite, draw up orders for supplies, keep records, and help with all of the other paperwork associated with keeping a business functioning. Those in service occupations were mostly employed as guards, janitors, and food service workers.

Training and Advancement

Industry support of education and training is substantial. Due to the constantly changing and advancing technology in the aerospace industry, employers are interested in well-informed, knowledgeable employees, who possess the skills needed to keep up with advancements in the industry. Firms provide on-site, job-related training to upgrade the skills of technicians, production workers, and engineers. Classes featuring computer skills and blueprint reading are common. Some firms reimburse employees for educational expenses at colleges and universities, emphasizing 4-year degrees and post-graduate studies.

Professionals, such as engineers and scientists, require a bachelor's degree in a specialized field. For some jobs, particularly in research and development, a master's or doctoral degree may be preferred.

Production workers may enter the aerospace industry with minimal skills. Mechanical aptitude and good hand-eye coordination are usually necessary. A high school diploma is preferred, but not required, and some vocational training in electronics or mechanics is also favored.

Unskilled production workers typically start by being shown how to perform a simple assembly task. Through experience, on-the-job instruction provided by other workers, and brief, formal training sessions, they expand their skills. Their pay increases as they advance into more highly skilled or responsible jobs. For example, machinists may take additional training to become tool programmers or tool and die or instrument makers. Inspectors are usually promoted from assembly, machine operation, and mechanical occupations.

Due to the increasing reliance on computers and computer-operated equipment, classes in computer skills are becoming more common. With training, production workers may be able to advance to supervisory or technician jobs.

To enter some of the more highly skilled production occupations, workers must go through a formal apprenticeship before they can become fully qualified for their positions. Machinists, sheetmetal workers, and electricians go through apprenticeships that can last up to 4 years. Apprenticeships usually include classroom instruction and shop training.

Entry level positions for technicians usually require a degree from a technical school or junior college. Companies sometimes retrain technicians to upgrade their skills or to teach different specialties. They are often taught traditional as well as new production technology skills, such as computer-aided design and manufacturing and statistical process control methods.

Earnings

Production workers in the aerospace industry earn higher pay than the average for all industries. Weekly earnings for production workers in aerospace manufacturing averaged about $844 in 1998, compared to $563 in all manufacturing, and $442 in all private industry. Above average earnings are due in part to the high levels of skill required by the industry, the high cost of aerospace products, and the need to motivate workers to concentrate on maintaining high quality standards in their work. Non-production workers, such as engineering managers, engineers, and computer specialists, generally command higher pay due to their advanced education and training.

Earnings in selected occupations in aerospace manufacturing appear in table 3.

Table 3. Median hourly earnings of the largest occupations in aircraft and parts manufacturing, 1997

Occupation	Aircraft and parts	All industries
Aeronautical and astronautical engineers	$34.69	$32.95
Mechanical engineers	24.89	24.33
First-line supervisors and managers/ supervisors-production and operating workers	20.70	16.62
Aircraft structure, surfaces, rigging, and systems assemblers, precision	19.65	16.63
Mechanical engineering technicians and technologists	18.52	18.17
Precision inspectors, testers, and graders	17.03	12.74
Machinists	15.48	13.38
Aircraft mechanics	15.23	17.80
Production inspectors, testers, graders, sorters, samplers and weighers	14.41	10.15
Assemblers and fabricators, except machine, electrical, electronic, and precision	11.39	9.25

In 1998, 30 percent of all workers in the aircraft and parts sector and 13 percent of workers in the guided missiles and space vehicles sector were union members or were covered by union contracts, compared to 15.4 percent of all workers throughout private industry. Some of the major aerospace unions include the International Association of Machinists and Aerospace Workers; the United Automobile, Aerospace, and Agricultural Implement Workers of America; and the International Union of Allied Industrial Workers of America.

Outlook

Employment in the aerospace industry is expected to increase by 22 percent over the 1998-2008 period, compared to the 15 percent growth projected for all industries combined. In the large aircraft and parts sector of the industry, employment is projected to grow by 25 percent, whereas employment in the smaller guided missiles and space vehicles sector is expected to increase by about 3 percent. Factors affecting the employment outlook in the aerospace industry include Federal defense expenditures, commercial aircraft sales, the growth of telecommunications, and exports.

Federal defense expenditures on the products of the aerospace industry have fallen dramatically since the late 1980s. During most of the 1980s, large defense purchases of aircraft and missiles, together with support of research to develop new military aerospace equipment, kept employment and output at a high level. Large cuts in Federal defense spending have caused an ongoing restructuring of the defense aerospace industry, and significant declines in employment, as firms adjust to the new, lower spending levels. Some companies are selling their defense-oriented business and others are merging. Although the aerospace industry is less dependent on defense spending than in the past, defense purchases still support a significant number of aerospace workers. Defense spending, although not expected to decline further, is not expected to return to previous levels (chart).

Although new employment opportunities will be limited in the defense-related sector of the aerospace industry, they should be much better in the sector supported by civilian aviation. Employment growth is expected in the production of commercial aircraft for both domestic and export purposes. Air passenger traffic is expected to increase at a healthy pace over the projection period. Also, aging aircraft may have trouble meeting worldwide and domestic fuel emissions and noise standards, requiring replacement or modification.

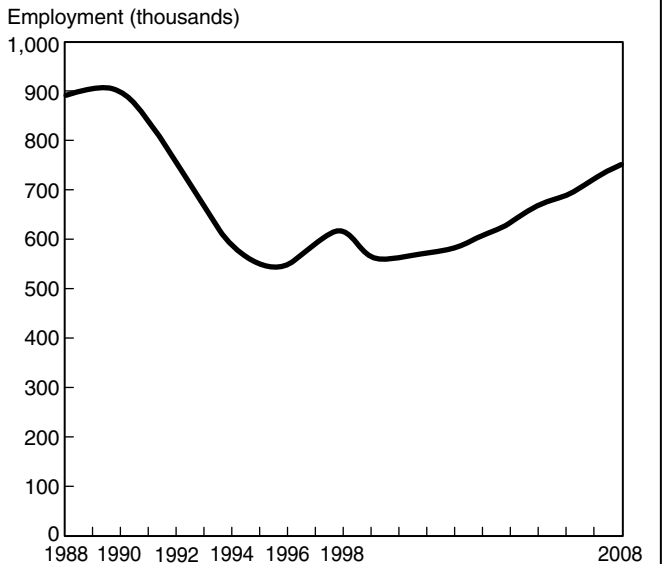
Commercial aircraft sales have been strong and they are expected to remain strong through 2008. Air travel has been rapidly growing over the years. In addition, environmental and safety concerns have highlighted the benefits of newer aircraft. As a result, airlines are purchasing more planes to meet the increased demand and to upgrade their fleets.

The expanded use of the Internet, direct broadcasting, and wireless communications services, such as cellular telephones and pagers, have increased the need for telecommunications equipment. Because satellites are widely used in telecommunications, this trend should spur further growth in the aerospace manufacturing industry.

Commercial exports have been rising strongly for years, reflecting the growth in overseas markets. Collaboration between domestic and foreign companies is becoming increasingly common as manufacturers seek to win sales in these growing markets and to share the substantial risks and costs of developing and producing new aerospace products. In addition to commercial exports, foreign military sales are also expected to bolster defense contractors, as countries around the world meet their defense needs with U.S. jet fighters, transports, and helicopters.

The continuing focus on advanced technology in aerospace manufacturing will lead to significant employment growth among professional specialty workers. Employment of engineers, for example, is expected to grow by 24 percent over the 1998-2008 period. Replacement needs also will be significant because large numbers of engineers who entered the industry in the 1960s are approaching retirement. Demand for computer engineers, computer scientists, and systems analysts is also expected to be very strong. Overall, professionals in the aerospace industry usually enjoy more employment stability than other workers. During slowdowns in production, companies prefer to keep technical teams intact to continue research and product development activities, in anticipation of new business. Production workers, on the other hand, are particularly vulnerable to layoffs during downturns in the economy when aircraft orders decline.

Employment in aerospace manufacturing is projected to grow more slowly than in the late 1980s



Sources of Additional Information

For additional information about the aerospace industry write to:

- Aerospace Industries Association of America, Communications Department, 1250 Eye St. NW., Washington, DC 20005. Internet: **http://www.aia-aerospace.org**
- American Institute of Aeronautics and Astronautics, Inc., Suite 500, 1801 Alexander Bell Dr., Reston, VA 20191-4344. Internet: **http://www.aiaa.org**

Information on the following occupations may be found in the 2000-01 *Occupational Outlook Handbook.*

- Aerospace engineers
- Aircraft mechanics and service technicians
- Blue-collar worker supervisors
- Computer engineers and scientists
- Computer systems analysts
- Electrical and electronics engineers
- Engineering technicians
- Machinists and numerical tool and process control programmers
- Mechanical engineers
- Metalworking and plastics-working machine operators
- Precision assemblers
- Tool and die makers
- Welders, cutters, and welding machine operators